

The Framework of Everything

Resolving Hilbert's 6th Problem of Axiomatizing Physics

Russell R. Smith

Revised: June, 2025

SmithCoDev@gmail.com

<https://orcid.org/0009-0001-5302-9646>

Key Words: General Relativity, Quantum Field Theory, Foundations of Physics, Formal Systems, Quantum Gravity, Non-Locality

This paper is permanently archived at Zenodo: <https://doi.org/10.5281/zenodo.14813498>.

License: CC BY 4.0 (Creative Commons Attribution 4.0 International)

ABSTRACT

When we say that a statement or theory X makes sense, we assert that there exists a formal system (Σ, \vdash_L) in which contradictions can't be derived ($\Sigma \not\vdash_L \perp$), but X can be $(\Sigma \vdash_L X)$, formally represented as:

$$X \text{ makes sense} \Leftrightarrow \exists(\Sigma, \vdash_L) | (\Sigma \not\vdash_L \perp) \wedge (\Sigma \vdash_L X) \quad [1] \quad (\text{See section 2.2})$$

The **EPR paradox** highlights a fundamental contradiction between the non-locality of quantum mechanics (QM) and the locality of general relativity (GTR) [2]. It follows that there isn't a formal system in which the mathematical constraints and interpretations of phenomena that modern physics offers make sense. We can resolve this by extending the formal system in which mathematics is developed, $\mathcal{FS}_{Math} = (F, \vdash_L)$ [3], into a comprehensive **formal system for physics** that goes beyond **Hilbert's Sixth Problem** (axiomatizing physics), and this new framework is:

$$\mathcal{FS}_{Physics} = (\beta, F, [P(Z) \Leftrightarrow Z], \vdash_L)$$

This system incorporates all known empirical observations (β) and defines the existence of physical entities (Z) through their inherent properties ($P(Z)$), thereby establishing a rigorous framework for constructing logically and ontologically consistent theories. For example, even if we could have an infinite property density, **a 1D string is indistinguishable from non-existence** offering tremendous insight about String Theory. From $\mathcal{FS}_{Physics}$ we can derive mathematics, physics, and explain all known phenomena, including entanglement, using the same logic ensuring that this framework is consistent with every process that we have of analyzing our reality, expressed as:

$$\mathcal{FS}_{Physics} \vdash_L \text{Mathematics} \wedge \text{Physics} \wedge \text{Explanations} \wedge \text{Ontology} \wedge \text{Philosophy of Physics}$$

This work is about providing a sensible means of deriving physics, not about proving everything within $\mathcal{FS}_{Physics}$ or its internal consistency, avoiding issues with **Gödel's Incompleteness Theorems**. Using this framework, the equations of GTR are mapped to a universal structure U in which the mechanism M is already quantized and explains both quantum and relativistic phenomena, thereby resolving the EPR paradox. This framework therefore offers "the same predictions as modern physics, without the contradictions" allowing unification through simplicity and logical consistency. From $\mathcal{FS}_{Physics}$ we can derive a **mechanism for quantum gravity**, and establish **time as a result of quantum phenomena**.

1 BACKGROUND, MOTIVATION, AND INTRODUCTION

René Descartes is widely credited with introducing the concept of a "plenum", a space entirely filled with subtle matter, in his work *Principia Philosophiae* (1644). While he did not use the term "ether" in the same way it would later be adopted in the 19th century, his concept functioned as a space-filling medium through which physical interactions, including light, motion, and pressure, could be transmitted. Descartes envisioned a universe without a vacuum, where all space was occupied by matter in constant motion, transmitting forces through direct mechanical contact rather than action at a distance [4]. In the 1860's James Clerk Maxwell published his equations that unite electricity and magnetism, and establish light as a wave. His derivations incorporated the concept of an ether to explain the interactions and pressure between the electric and magnetic fields [5]. In 1881 Albert Michelson devised an experiment using an interferometer to test the existence of this ether, by measuring differences in the speed of light along perpendicular arms. Any variation in light speed due to motion through the ether would cause a measurable phase shift in the interference pattern. Since no such phase shift was observed at the expected magnitude, the existence of the ether could not be confirmed. This was attributed to both limitations in the equipment due to vibrations, and potential ether dragging. However, ether dragging is not consistent with stellar aberration, which requires that a telescope be slightly tilted in the direction of motion to observe a star. This experiment was then repeated in 1887 using more precise equipment, with the same outcome. This later test is now known as the Michelson-Morley Experiment (MME) [6].

In 1905, Einstein published his work on special relativity, which is based on perhaps the most famous postulate of all time: "light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body" [7]. This work was then followed by his theory of general relativity in 1915 [8]. While this postulate is consistent with the results of the MME, according to some sources, Einstein based it more on thought experiments rather than the results of the MME itself [9]. However, the MME, the interferometers used at LIGO to detect gravitational waves [10], and experimental confirmation of time dilation and gravitational lensing shed light on how precisely the aforementioned postulate matches observation. While there doesn't appear to be a substantial problem in this model, complications escalate quickly with the advancement of QM. This escalation occurs because the Schrodinger equation not only describes particles via a wave function, but it allows multiple particles to be described by a single wave function in what is called an entangled state [11]. Since entangled particles share a wave function, they can't be described independent of each other establishing a type of "instantaneous correlation" between them. For example, QM predicts that if one entangled particle is found spin-up along a given axis, the other will be found spin-down, with a statistical relationship stronger than classical correlations allow. Einstein, Podolsky, and Rosen therefore proposed a thought experiment in which entangled particles are spatially separated by a sufficient distance, and then measured in such a way that any signal traveling at or below the speed of light would not have enough time to propagate between them to establish the observed correlation. Therefore, if the correlation is still present after observation, this would suggest that either: A) locality doesn't hold within QM or; B) there must be local hidden variables that establish the correlation at the moment of entanglement (e.g., two different colored socks placed in boxes and separated. When you open one box, you instantly know the color of the other sock without a transfer of information [12]). However, if there isn't a correlation then QM would have to be incomplete. This thought experiment is known as the EPR Paradox [13], and it represents a substantial problem for physics that hasn't been properly resolved.

In 1964, John Bell published perhaps one of the most subtle yet ingenious theorems within physics. Bell's Theorem establishes a constraint on the types of correlations that are possible between entangled particles under the assumptions of locality and realism.

$$\text{Locality} \wedge \text{Realism} \quad (\text{Assumed in Bell's Theorem})$$

When we insert the quantum correlation function into Bell type inequalities, for certain entangled states the inequality doesn't hold [2]. This violation of Bell inequalities has been experimentally confirmed without loopholes [14], establishing that at least one of the two premises on which Bell's Theorem is developed must

be false. Therefore:

$$\neg Locality \vee \neg Realism \quad (\text{Required by violations of Bell's Inequality})$$

Some interpretations of QM therefore abandon realism in favor of locality, while other interpretations, like that which is supported by Maudlin, argue that QM is non-local [15]. This research establishes that for any logically consistent theory, if at least some aspect of a particle didn't exist before measurement, then there wouldn't be anything to measure. It follows that realism holds, and therefore locality doesn't, and this relationship is expressed as:

$$(\neg Locality \vee \neg Realism) \wedge Realism \Rightarrow \neg Locality \quad (\text{Required by logic as shown below})$$

It should be clarified that the speed of light is intrinsically built into the geometry of spacetime, establishing a fundamental causal limit such that no information or causal influence can propagate faster than light [16]. This remains true even if we consider entangled particles as part of the same object. While speculative theories, such as certain interpretations within String Theory, propose mechanisms like wormholes to conceptually link entangled particles [17], the theoretical nature presents significant challenges that aren't always realistic (e.g., sometimes there can't be such shortcuts through spacetime). With that said, there is a direct conflict between the locality of GTR and the non-locality of QM that establishes the current state of physics as:

$$Locality \wedge \neg Locality \Rightarrow \perp \quad (\text{The state of modern physics confined to spacetime})$$

This result is a bit unexpected since both QM and GTR make predictions that match observation typically with less than 1% error. In relation to entanglement, Bell himself concluded that 'the signal involved [in any hidden variable theory reproducing quantum mechanical correlations] must propagate instantaneously, so that such a theory could not be Lorentz invariant' [2]. This instantaneous propagation, being faster than light, precisely highlights the deep tension between the relativistic principle of locality and the non-locality of QM. Now, I believe that most physicists have adopted the interpretation in which entanglement doesn't require a signal or transfer of information between the particles. I also believe it can be argued that the correlation information of entangled particles is stored in non-local variables that are unique to each particle, therefore eliminating the need for a signal between them. However, if this is not the case, the only means for an entangled particle to have information that it didn't already have is if information is transferred to it.

This framework provides a process for taking all of the observations in physics, even those that appear to be paradoxical, and logically constructing a universal structure U in which quantum and relativistic phenomena share a well-defined mechanism M . All of our explanations and understanding about how to interpret phenomena are logically derived from $\mathcal{FS}_{Physics}$, where dependence on F (a mathematical framework like ZFC) ensures that we can model phenomena mathematically thereafter. As an analogy, just as we can setup a system of equations and then use algebra to derive the solution set, we can setup a system of logical statements and use logic to derive U . **By changing from spacetime to U we can let go of locality, without violating causality, allowing us to resolve the EPR paradox.** In section 4, the equations of GTR are mapped to U to show that the same predictions are made. To explain this, think of the geometry of U as the geometry of the spacetime manifold. By introducing the universal mechanism M , we can alter this geometry, while maintaining the same relativistic predictions, until M also explains quantum phenomena, allowing for simplistic unification. For conceptual purposes, think of M like an ether that satisfies the following: 1) M weakly interacts with photons (or any object) so as to not be measurable locally, but over vast distances those interactions compile resulting in phenomena like gravitational lensing; and 2) M is comprised of quantized existences that are individually not measurable to us, but when they interact with each other their properties superimpose to form particles that we can observe. So M allows us to unite the observations of quantum and relativistic phenomena through an already quantized medium that weakly interacts with objects to produce relativistic phenomena, and that interacts with itself to produce quantum phenomena. The fine line that we walk to make this work is governed herein by formal logic.

It's important to clarify that the concepts of a weakly interacting ether, and quantizing ether [18], have been explored in physics before, though they haven't gained widespread acceptance. However, when

we apply this framework to unite quantum and relativistic phenomena, it reveals that numerous existing concepts within physics must undergo significant changes for a consistent resolution. I believe that previous approaches failed precisely because they didn't implement enough of these fundamental conceptual shifts necessary to resolve the underlying problems. Consequently, within U , many established concepts in modern physics must be re-evaluated and potentially redefined in exchange for achieving logical consistency.

So why is it important for physics to make sense (as defined above)? Acknowledging that any foundational argument relies on assumptions that can be challenged, this framework offers a compelling answer. By allowing us to explain all known phenomena in a sensible way, this framework demonstrates that there was never a reason to presume that the universe doesn't make sense. This research establishes that the unification of physics has been fundamentally impeded by logical error giving a strong motive for us to align research with this framework. $\mathcal{FS}_{Physics}$ acts as a guide for researchers to be able to work more efficiently. There are many seemingly strange concepts within physics, such as the quantization of particle spin about any measured axis as first discovered by the Stern-Gerlach experiment, and formal logic allows us to collectively make sense of such findings.

2 THE FRAMEWORK OF EVERYTHING

The language of the universe is logic, and when the appropriate logical framework is applied, this language extends to mathematics. However, if mathematics is applied before phenomena are logically understood, we risk constructing mathematical models that yield correct numerical predictions for the wrong reasons, creating the illusion that the universe is paradoxical. Consequently, the difficulty in unifying physics stems from treating formal logic and mathematics as commutative when they are not.

2.1 DEFINITIONS

Let $\beta = \{\text{All well-established scientific observations including: Casimir effect, Wave-particle duality, Quantum entanglement, Quantum tunneling, Invariance of the speed of light, Gravitational lensing, Gravitational redshift, Gravitational waves, Lorentz time dilation and gravitational time dilation, Black holes, The expansion of the universe}\}$

$$G_{L,\beta} \in \mathcal{G}, \text{ where } \mathcal{G} = \{G' | G' \text{ is a universal geometry for modeling } \beta\}$$

$$M_{L,\beta} \in \text{Mech}, \text{ where } \text{Mech} = \{M' | M' \text{ is a mechanism in } G_{L,\beta} \text{ causing } \beta\}$$

$$U_{L,\beta} = (G_{L,\beta}, M_{L,\beta})$$

A **property** P is an intrinsic, non-trivial attribute (e.g., mass, charge) of an entity that is independent of subjective perception or its geometrical characteristics.

An entity Z **exists** if and only if Z possesses a property: $P(Z) \Leftrightarrow Z$ (e.g., An imagined sphere doesn't exist because it doesn't have any attributes that are independent of the mind. An electron exists because charge isn't dependent on subjective perception.)

2.2 FORMAL LOGIC

For a statement to make sense, there must be a formal system in which it makes sense in relation to. That is, logic governs how new statements are derived from a set of assumptions in a sensible way. For example, if $\Sigma = \{A \wedge (B \vee C)\}$, $(A \wedge B) \vee (A \wedge C)$ makes sense (i.e., is derivable) within classical logic (since the Distributive Law holds), but doesn't necessarily make sense within quantum logic (the Distributive Law isn't assumed). Within the formal system $(\{p, \neg p\}, \vdash_L)$, p doesn't make sense since we can derive a contradiction, but that doesn't prevent p from making sense within some other system. For example, $(\{p\}, \vdash_L)$ just means that we are going to assume p and then use our rules of inference to make conclusions. As long as contradictions can't be derived, p makes sense within the given system. This might appear counter intuitive, but logic is the study of valid reasoning based on whatever premises are made. This is why it is important in physics to start

with a set of assumptions that everyone can reasonably agree on, and then let the rules of logic take it from there. This framework therefore starts with the assumptions of $\beta, F, P(Z) \Leftrightarrow Z$, in which we can logically derive everything that is needed to make sense of reality. Within this framework, everything in physics is derived from $\mathcal{FS}_{Physics}$, from the mathematical theorems, to the mechanisms that explain phenomena. To demonstrate this, let $P_S(Z)$ represent a specific type of property like mass. Since everything studied within physics has a property, $(P(Z) \Leftrightarrow Z, \vdash_L)$ governs how all phenomena must be understood. Therefore, the following logical forms must hold for any sensible theory in physics:

- 1) $P_S(Z) \Rightarrow Z$ (Original Statement)
- 2) $\neg Z \Rightarrow \neg P_S(Z)$ (Contrapositive)
- 3) $Z \not\Leftrightarrow P_S(Z)$ (converse nonimplication)

So why is this important? Consider the following examples in which we define $C(Z)$ as a property that allows for interactions or constraints. Setting $P_S(Z) = C(Z)$, allows us to construct the following kinds of arguments:

- A. $C(Z) \Rightarrow Z$ ensures that for the wave function to serve a purpose it would have to represent a physically existing entity, negating some interpretations of QM.
- B. Let's assume that there is a boundary to space. By definition, everything that exists must exist within said boundary. Since nothing exists beyond the boundary, $\neg Z \Rightarrow \neg C(Z)$ establishes that nothing can prevent an object from moving beyond it. By contradiction we can conclude that space doesn't have a boundary, and is therefore infinite in all defined dimensions. It is the fact that space has a geometry, but not any properties, that allows it to act as the backdrop in which everything freely moves. One of the purposes of spacetime is to provide the space for objects to move, but this framework establishes that spacetime isn't needed for this purpose.
- C. $Z \not\Leftrightarrow C(Z)$ establishes that we can consider entities that exist without measurable properties (e.g., a magnetic field might not be measurable using a stick). This is valuable because it allows us to begin to construct the universal structure $U_{L,\beta}$ in which the photon is the fastest measurable entity, and other entities (e.g., non-local hidden variables) can exist to propagate quantum information faster than light through weak interactions, resolving the EPR paradox without violating causality or the No-Signaling Theorem within $U_{L,\beta}$. These interactions must be weak enough that they remain undetected locally (e.g., during the Michelson-Morley experiment), but over vast distances the interactions compile resulting in phenomena such as gravitational lensing. We model this mathematically herein.

By constructing a sufficient set of logical statements, we can derive the universal structure $U_{L,\beta}$ in which both quantum and relativistic phenomena share a common mechanism. Logic tells us if we are on the right track, and it gives answers that physicists have written off as being philosophical. The universe is vastly simpler than what modern physics portrays, as logical errors have introduced wildly imaginative concepts that prevent sensible unification.

2.3 KNOWN LAWS OF EXISTENCE

Since every entity studied within physics has a property, $(P(Z) \Leftrightarrow Z, \vdash_L)$ governs how every logically consistent theory must be understood. Using the logical forms above, we can derive the following rules, called Laws of Existence, that will help us to logically construct the universal structure $U_{L,\beta}$:

Self-Causation Law

Let $S(Z)$ represent the property of self-causation.

- 1) $S(Z) \Rightarrow Z$ (An entity can have the property of self-causation.)
- 2) $\neg Z \Rightarrow \neg S(Z)$ (An entity can't cause itself to exist.)

- 3) $Z \not\Rightarrow S(Z)$ (An entity can exist that isn't self-causal.)

Discussion: This establishes that if an entity does not exist, it cannot bring itself into existence, but if an entity does exist, it can intrinsically possess all of the laws and attributes needed to self-cause internal changes in states (e.g., no need for a universal temporal dimension). This can be represented using the following causal loop:

$$S(Z)_D = s_{Z,0} \rightarrow s_{Z,1} \dots s_{Z,n-1} \rightarrow s_{Z,n} \rightarrow s_{Z,0}$$

where the subscript D signifies a deterministic relationship in which each state $s_{Z,i}$ can only be followed by one possible next state. For Z to be deterministic, it must possess all of the laws and information that are necessary to determine all of its states. For example, conservation of momentum is a law, and thus when particles decay, the information establishing this law must be present within the particle otherwise there isn't any reason for the particle to consistently behave a particular way. We can therefore consider the case in which such information isn't present within the particle, introducing a non-deterministic or free will state, formally represented as:

$$S(Z)_{FW} = s_{Z,0} \rightarrow s_{Z,1} \dots s_{Z,k-1} \rightarrow (s_{Z,k,0} \vee s_{Z,k,1} \vee \dots) \rightarrow s_{Z,n} \rightarrow s_{Z,0}$$

Both causal loops function in the same way, but $S(Z)_{FW}$ has a lack of information regarding the $s_{Z,k}$ state introducing a free-will choice. Now we are use to concepts like "every action has a reaction" but that requires information to be enforced, and when that information isn't present, there isn't any reason to conclude that it holds. Free will is therefore the absence of certain laws and information producing a non-deterministic state, and our measurement of time is possible because of these quantum processes.

Purpose: In GTR, spacetime is a 4-dimensional manifold in which the past, present, and future all exist, but this framework establishes that to be a nonsensical interpretation of reality (since it isn't non-local). However, this framework tells us that we can logically make the same predictions, without the contradictions, by allowing objects to self-cause their motion through causal loops that are governed intrinsically, and therefore don't depend on a universal temporal dimension. This means that our concept of time can only be based on the distance that objects move between events explaining why the speed of light is measured as invariant. The internal workings of an atom are dependent on the propagation of force carrying particles ensuring that even the atomic clock is subject to this same principle. Faster-than-light (FTL) signals that are needed to propagate quantum information through $M_{L,\beta}$ therefore don't violate causality allowing us to resolve the EPR Paradox. To recover time dilation, $M_{L,\beta}$ has to regulate motion in the same capacity that spacetime was said to. With this approach, all known phenomena can be said to occur within Euclidean 3-space more accurately matching observation, where a temporal dimension is only necessary on paper.

Constraint Law

$C(Z)$ (defined in the Overview)

- 1) $C(Z) \Rightarrow Z$ (If you can interact with an entity, that entity must first exist.)
- 2) $\neg Z \Rightarrow \neg C(Z)$ (If an entity doesn't exist, you can't interact with it.)
- 3) $Z \not\Rightarrow C(Z)$ (Entities can exist, that we can't interact with.)

Discussion: This establishes that if some aspect of a particle doesn't exist before measurement, then it couldn't ever be measured, and therefore realism must hold. When you write down equations, the ink and paper exist, but the numbers and symbols are representations of the concepts in mathematics. Mathematics therefore doesn't exist and thus it can't be used as a causal agent. In Quantum Field Theory (QFT), the fields are continuous, but mathematical operators are the only explanations for quantization ensuring logical error. This framework therefore corrects this issue.

The Isomorphism Theorem of Space (ITS)

Claim: In the context where points in space are represented as vectors, space is isomorphic to \mathbb{R}^n for some $n \geq 3$.

Clarification: The universe existed long before human interaction. Our reality therefore doesn't depend on or care about us being able to take a measurement. In reality, particles exist somewhere regardless of our observation, and therefore there is a defined distance between them.

Proof: Space has a geometry, but it doesn't have any properties, and therefore space doesn't exist. Since space doesn't exist, nothing exists to prevent the algebraic operations of Euclidean vector spaces from holding. Let S represent points in space, and \mathbb{R}^n be the n -dimensional Euclidean space for some $n \geq 3$. Define $\phi : \mathbb{R}^n \rightarrow S$ by $\phi(\langle v \rangle) = (v)$, where each vector $\langle v \rangle \in \mathbb{R}^n$ is mapped to a corresponding point $(v) \in S$. By the Law of Excluded Middle, an existence Z either exists at (v) , or it doesn't. If Z exists at (v) , then (v) must first be well-defined. If there isn't an existence at (v) , then by the Constraint Law (#2), nothing exists at (v) to prevent Z from moving to (v) . Therefore, $\forall \langle v \rangle \in \mathbb{R}^n$, (v) is well-defined. It is now necessary to show that ϕ satisfies the requirements of an isomorphism. Let $\langle v_1 \rangle, \langle v_2 \rangle \in \mathbb{R}^n$:

- **Injective:** Suppose that $\phi(\langle v_1 \rangle) = \phi(\langle v_2 \rangle)$. It follows that $(v_1) = (v_2)$, and thus $\langle v_1 \rangle = \langle v_2 \rangle$. Therefore ϕ is injective.
- **Surjective:** For any point $(v_i) \in S$, $\exists \phi^{-1}(v_i) = \langle v_i \rangle \in \mathbb{R}^n$. Thus ϕ is surjective.
- **Linear:** $\phi(\langle v_1 + v_2 \rangle) = (v_1 + v_2) = \phi(\langle v_1 \rangle) + \phi(\langle v_2 \rangle)$, and $\phi(c\langle v_1 \rangle) = c(v_1) = c\phi(\langle v_1 \rangle)$ and thus ϕ preserves vector addition and scalar multiplication.

Since ϕ is bijective and preserves vector operations, it is an isomorphism between \mathbb{R}^n and S .

QED

Purpose: It is the fact that space has a geometry but not any properties, that allows it to act as the background in which everything freely moves without the need for spacetime.

Information Law

$\mathcal{I}(Z)$: The property of information.

- 1) $\mathcal{I}(Z) \Rightarrow Z$ (If an entity has information, then said entity exists.)
- 2) $\neg Z \Rightarrow \neg \mathcal{I}(Z)$ (If an entity doesn't exist, it doesn't have any information.)
- 3) $Z \not\Rightarrow \mathcal{I}(Z)$ (Entities can exist, without having information.)

Purpose: Information necessitates existence. For the concept of information to be meaningful in physics, that information has to be exchangeable between entities which is not a requirement for existence itself. If quantum particles are assumed to not have certain information until measurement, this requires a signal.

Law of Ontological Continuity

$NE(Z)$: An entity Z can be created from non-existence.

$Began(Z)$: An entity Z had a beginning.

$Perm(Z)$: An entity Z is constructed of a permutation of pre-existing entities.

1. Self-Causation Law \wedge Constraint Law $\Rightarrow \neg NE(Z)$

$$2. \neg NE(Z) \wedge \text{Began}(Z) \Rightarrow \text{Perm}(Z)$$

Purpose: An entity that doesn't exist can't have the property of self-causation, nor can it be interacted with to cause its existence, and thus existence can't be created from non-existence. Therefore, any entity that begins to exist is formed from a permutation of pre-existing entities. This establishes that the vacuum of space contains existence to account for phenomena like the Casimir effect.

The Point Entity Theorem

Claim: Point entities can't exist.

Clarification: You can't take the Gaussian distribution and apply a limit to make the width of the curve identical to zero in a useful way. This has implications for the Dirac Delta Function that render a contradiction when applied to point particles. These statements are proven mathematically in Appendix A, and are represented as ZTIT, NZLT, and DDFT below.

Proof: Let Z be a point entity with property density $\rho(Z)$.

$$\begin{aligned} \text{Point}(Z) &\Rightarrow [\text{Volume}(Z) \equiv 0] \\ [\text{Volume}(Z) \equiv 0] \wedge \text{ZTIT} \wedge \text{NZLT} \wedge \text{DDFT} &\Rightarrow [\rho(Z)\text{Volume}(Z) \equiv 0] \\ [\rho(Z)\text{Volume}(Z) \equiv 0] &\Rightarrow \neg P(Z) \\ \neg P(Z) &\Rightarrow \neg Z \\ \neg Z \end{aligned}$$

QED

Purpose: While point-particles are an excellent mathematical simplification, they can't be used in any sensible theory other than for such purposes.

1D Entity Theorem

Claim: 1-dimensional entities can't exist.

Proof: Let Z be a 1-dimensional entity, $X = \{x|x \text{ is an internal point on } Z\}$, and $H(Z, x)$ be a binding property holding Z together at x .

$$\begin{aligned} \text{ITS} &\Rightarrow \forall x \in X, x \text{ is well-defined} \\ \text{Dim}(Z) = 1 \wedge x \text{ is an internal point} &\Rightarrow x \text{ divides } Z \\ x \text{ divides } Z \wedge \text{Point}(x) \wedge \text{The Point Entity Theorem} &\Rightarrow \neg H(Z, x) \\ \neg H(Z, x) \wedge x \text{ is arbitrary} &\Rightarrow \forall x \in X, \neg H(Z, x) \\ \forall x \in X, \neg H(Z, x) &\Rightarrow \neg Z \\ \neg Z \end{aligned}$$

QED

Purpose: Strings in String Theory can't exist.

2D Entity Theorem

Claim: 2-dimensional entities can't exist

Proof: Let Z be a 2-dimensional entity, $X = \{x \mid x \text{ is a 1D entity dividing } Z\}$, and $\Phi(Z, x)$ be the binding flux holding Z together along x .

$$x \text{ divides } Z \wedge x \text{ is 1D} \wedge \text{1D Entity Theorem} \Rightarrow \neg\Phi(Z, x)$$

$$\neg\Phi(Z, x) \wedge x \text{ is arbitrary} \Rightarrow \forall x \in X, \neg\Phi(Z, x)$$

$$\forall x \in X, \neg\Phi(Z, x) \Rightarrow \neg Z$$

$$\neg Z$$

QED

Purpose: 2-branes in M-Theory don't exist.

Volumetric Existence Theorem

Claim: It is mathematically feasible that a 3-dimensional entity exists.

Clarification: The 1D Entity Theorem and the 2D Entity Theorem establish that if you take a cross section of either a 1D or 2D entity, it is impossible for anything to be holding it together. When you take a cross-section of the 3D entity, this is not the case.

Proof: Let Z be a 3-dimensional entity, \mathcal{L} be the maximal chord of Z , $A = \{a \mid a \text{ is a 2D cross-section of } Z \text{ that is } \perp \mathcal{L}\}$, and $|P(Z)|$ be the total property value of Z (e.g., total charge). Define $|P(x_p)| : [0, |\mathcal{L}|] \rightarrow [0, |P(Z)|]$ as $|P(x_p)| = \int_0^{\mathcal{L}} a(x_p) \rho(x_p) dx$. Thus, if $a(x_p) \rho(x_p) > 0 \forall x_p \in [0, |\mathcal{L}|]$, then Z exists.

QED

Purpose: This, in conjunction with the 1D Entity Theorem and the 2D Entity Theorem establish that existence requires at least a 3-volume.

Missing Geometry Theorem

Claim: If a physical system Q is defined by the set of existences E , then only the elements within E exist.

Proof: Let P_Q be the set of points within a volume enclosing Q . By the Volumetric Existence Theorem, $\forall e_i \in E, \exists P_{e_i} | P_{e_i}$ is the minimal set of points enclosing e_i . Let Z be an entity spatially defined by the set of points $P_Q \setminus \bigcap P_{e_i}$. Since $\neg P(Z)$, Z doesn't exist.

QED

Purpose: Only existence exists. For example, what we call a 'star' does not exist as a singular entity; rather, it is a configuration of underlying existences. These existences persist independently, and the 'star' is merely a label we assign to their arrangement.

3 ATTRIBUTES OF THE UNIVERSAL STRUCTURE $U_{L,\beta}$

Typically a section in physics that establishes a universal structure like $U_{L,\beta}$ would have to be very rigorous. However, the Laws of Existence allow us to derive it very informally, and then check the solution by showing that it works. Thus we can avoid unnecessary complexities as follows.

The Isomorphism Theorem of Space \Rightarrow Space $\cong \mathbb{R}^n$ for some $n \geq 3$: Space has a geometry but it doesn't have any properties, and thus by definition it doesn't exist. By the Constraint Law, if particles are placed in space, they are free to move in all defined dimensions as they transition through their causal loops $S(Z)$. We therefore initially assume $G_{L,\beta} \cong H \subseteq \mathbb{R}^3$ and add to it as needed.

The Constraint Law \Rightarrow Only existence can interact with particles: When a photon undergoes gravitational lensing, this can only occur if the space through which it propagates contains entities that interact with it. While space itself lacks intrinsic properties, entities that exist within it can produce the effects attributed to GTR, even if their properties are not directly detectable. Thus, the mechanism $M_{L,\beta}$ can initially be described as spanning $G_{L,\beta}$ like a field, possessing properties that are not directly measurable. It should be noted that the interaction between a photon and $M_{L,\beta}$ does not have to be entirely absent, only weak enough that it remains undetectable locally, yet accumulates over vast distances to manifest as phenomena like gravitational lensing.

The Law of Ontological Continuity \Rightarrow The totality of existence is fixed: The Casimir Effect illustrates that quantum field fluctuations permeate space even in the absence of particles [19]. The emergence of quantized particles is only possible if the mechanism $M_{L,\beta}$ itself consists of fundamental quantized existences, referred to as quantistances, spanning $G_{L,\beta}$, such that:

1. Each quantistence individually lacks directly measurable properties, as permitted by the Constraint Law.
2. Interactions between quantistances collectively produce measurable properties, which we identify as particles.

Thus, $M_{L,\beta}$ unifies all fields in QFT into a single field and serves as the underlying mechanism for the quantization described in both QFT and QM.

Just utilizing these three Laws of Existence, the observations in β can be explained logically as supported in section 5. Since this framework is also dependent on F , this ensures that the phenomena can also be accurately modeled mathematically within $U_{L,\beta}$. Now, it is always possible that new observations might require that we alter the above description of $U_{L,\beta}$ in accordance with the Laws of Existence. However, this doesn't appear to be likely considering that only one relativistic and 2 quantum phenomena are needed to fully logically describe $U_{L,\beta}$. That is, it appears that new discoveries will fit within the description of $U_{L,\beta}$ above without modifications. In this case, physicists can develop their theories using an instance of $U_{L,\beta}$ (develop equations that mathematically model $U_{L,\beta}$ as described above). While the purpose of this framework is not to provide mathematics, an example is provided in the following section.

4 MAPPING THE PREDICTIONS OF GTR TO $U_{L,\beta}$

The purpose of this framework is to align physics with logical principles, not to produce mathematical theories. However, to show that correct mathematical theories can be developed within $U_{L,\beta}$, the following derivation is established. As shown above, spacetime is not necessary to explain the elements of β and it results in unnecessary complexities when it comes to uniting with QM. However, the mathematics of GTR doesn't have to be reinvented, it just has to be mapped from spacetime to $U_{L,\beta}$, with phenomena interpreted in accordance with the Laws of Existence, as follows.

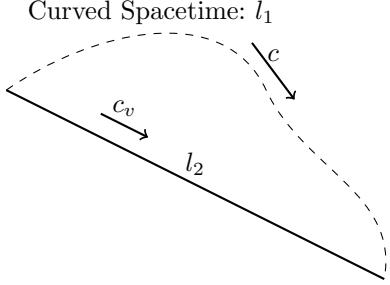


Figure 1: A geodesic of spacetime (dashed), of length l_1 , is shown where two points thereof are intersected by a line l_2 in 3-space Euclidean. A photon travels at speed c along l_1 , projected as speed c_v on l_2 , illustrating a transformation from spacetime to $U_{L,\beta}$ where the mechanism $M_{L,\beta}$ explains phenomena.

Consider a photon traveling at speed c along the geodesic of spacetime, where c is projected onto a line l_2 in $U_{L,\beta}$, as shown in Fig. 1. Thus, if $l_1 = ct$, then $l_2 = [c\tau = \int_0^t c_v dt]$ where c_v is the speed of light along l_2 , and τ is the proper time. Therefore:

$$cd\tau = c_v dt \quad (7)$$

The metric equation of General Relativity (GTR) is:

$$cd\tau = c_v dt = \sqrt{g_{\mu\nu} dx^\mu dx^\nu}$$

Thus:

$$\begin{aligned} cd\tau &= \sqrt{g_{\mu\nu} dx^\mu dx^\nu} && (\text{[20], GTR modeled with spacetime, 8}) \\ c_v &= \sqrt{g_{\mu\nu} \frac{dx^\mu}{dt} \frac{dx^\nu}{dt}} && (\text{GTR modeled with } U_{L,\beta}, 9) \end{aligned}$$

The speed of light is built into the geometry of spacetime, but the same is not true of $U_{L,\beta}$. Equation 9 only pertains to particles and not the quantistances comprising $M_{L,\beta}$, allowing for the FTL transmission of quantum information without violating causality. The speed of light varies universally as c_v (see Fig. 1), but since each reference frame measures time based on distances, each reference frame measures the speed of light as c . $M_{L,\beta}$ is the mechanism that makes all of this possible.

Equation 8: GTR treats time as independent of force carriers like photons, meaning that time would continue to pass even in their absence. Each reference frame has its own proper time, which is determined by the structure of spacetime. In classical mechanics, if a runner travels a distance d , at a velocity v , for a time t , these parameters are related by the equation $d = vt$, where $[v] = [\text{distance}/\text{time}]$ ($[x]$ represents the units of x).

Equation 9: The Laws of Existence establish that entities can inherently have the attribute we associate with time through their causal loops. Thus, everything can be said to move within $U_{L,\beta}$, where $M_{L,\beta}$ regulates this motion, and there isn't a physical dimension of time. If we want to plot the position of everything in $U_{L,\beta}$ as it changes, then (on paper) we have to add an axis we call time that doesn't exist in reality. Our concept of time is thus tied to the distance that certain objects move between events (in the old days this was stars). For example, suppose that our measurement of time for the aforementioned runner is the distance D that a photon travels while they are running (see the Self-Causation Law). In this context, $d = vD \Rightarrow v = d/D$, and therefore $[v] = []$. Thus, what we call velocity in classical mechanics is just the distance traveled by the runner divided by the distance traveled by the photon, multiplied by some conversion factor that allows us to use equations such as $d = vt$.

5 EXPLAINING SCIENTIFIC OBSERVATIONS WITH $M_{L,\beta}$

The quantistances that comprise $M_{L,\beta}$ are not directly measurable until in particle form. Thus, there isn't a reason to assume that they conform to our known physical laws, including light speed limitations,

until they are in such state. $M_{L,\beta}$ can thus be thought of as a “behind the scenes mechanism” that causes all the observations in β to occur. Some examples are as follows:

- Quantum entanglement: Violations to the CHSH inequality (now experimentally verified without loopholes [14]) imply that faster than light (FTL) causal signals are required to explain entanglement, yet GTR doesn’t allow for such signals [2]. $M_{L,\beta}$ resolves this paradox since $M_{L,\beta}$ isn’t restricted by our known physical laws. $M_{L,\beta}$ therefore allows for both an FTL causal signal to propagate between entangled particles, or for each entangled particle to store the correlation information in FTL variables that are unique to each particle. This doesn’t violate the No-Signaling Theorem since $M_{L,\beta}$ can’t be sufficiently interacted with to coordinate a meaningful message.
- Black holes: By the Information Law, you can’t have a field without existence. $M_{L,\beta}$ provides that existence for the gravitational field to be distributed through. Equation 9 establishes that the speed of light drops to zero at the event horizon as measured by a distant observer. However, since time is a function of the distance objects travel between events, the reference frame near the event horizon still measures the speed of light to be c .
- Singularities: See the Point Entity Theorem.
- Wave-particle duality: When a particle is observed, the quantistances comprising it can be said to act more as a rigid whole resulting in particle-like behavior, while $M_{L,\beta}$ can facilitate the quantistances interacting more freely when not observed resulting in wave-like behavior.
- Superposition: This framework allows for particles to transition back and forth between measurable and unmeasurable states. $M_{L,\beta}$ is present to regulate how the quantistances making up a particle act to align with the predictions of the Schrodinger equation.
- Quantum tunneling: $M_{L,\beta}$ allows for a particle to cross a potential barrier in the unmeasurable state.
- Casimir Effect: described above.
- Invariance of the speed of light: Time is a function of the distance objects move, and thus the speed of light is always measured as invariant as stated above.
- Lorentz and gravitational time dilation: $M_{L,\beta}$ exists to guide a photon along one of its geodesics causing time dilation.
- Universal expansion: $M_{L,\beta}$ exists to drive the expansion.
- Gravitational waves: $M_{L,\beta}$ exists for waves to propagate through.
- The arrow of time: Entities transition through their causal loops $S(Z)$, and we measure time based on the distances traveled. Thus, time doesn’t exist, ensuring that it isn’t reversible.
- The nature of the wave function: Both the Constraint Law and the Information Law necessitate that the wave function represents a real and existing entity. Without existence, the wave function could neither induce change nor retain information.

6 MECHANISM FOR QUANTUM GRAVITY

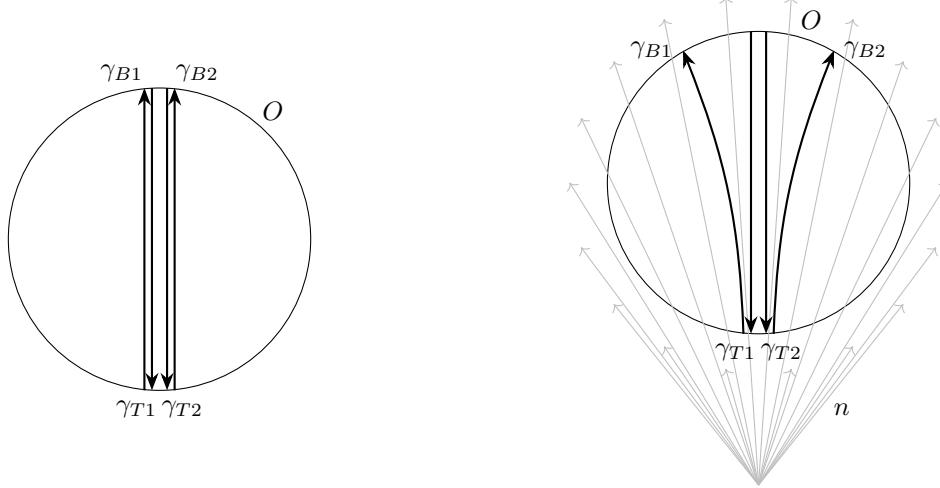


Figure 2: The left side depicts an object O as a spherical shell, where virtual particles are exchanged internally. Each particle produces a force on O , due to a change in momentum, both on emission and absorption, and these forces cancel out. (right) When O is moved into a non-uniform field $n = c/c_v$, representing the index of refraction of space, the particles change paths resulting in the forces produced during emission and absorption no longer canceling.

Consider the object O in Fig. 2 (left), represented as a spherical shell. Internal exchanges of virtual particles, denoted as $\gamma_{B1}, \gamma_{B2}, \gamma_{T1}$, and γ_{T2} , occur isotropically, resulting in a net cancellation of momentum-related forces. Using equation (9), the index of refraction of space n can be expressed as:

$$n = \frac{c}{c_v}$$

When O is placed within a non-uniform field characterized by n (see equation 9), as illustrated in Fig. 2 (right), the symmetry of virtual particle exchanges is disrupted (e.g., light curves towards the higher index of refraction). Particles traveling from a weaker gravitational field to a stronger one propagate in a straight line, whereas those moving in the opposite direction experience curvature due to the spatial variation in n . Preliminary calculations suggest that if O represents an atomic nucleus and the virtual particles correspond to force carrier exchanges, the resulting net force aligns with the gravitational equation because of interactions with $M_{L,\beta}$.

7 CONCLUSION

The paradoxes observed in physics, such as non-causal relations in quantum mechanics, stem from the assumption that logic and mathematics are commutative. However, these inconsistencies do not reflect the fundamental nature of reality, as reality itself is not contradictory. To resolve these issues, this work first examines the foundational development of mathematics and physics and then establishes a framework in which both disciplines share a common logical foundation. Since mathematics is inherently dependent on logic, logical principles must be applied to physics prior to mathematical formalization. This ensures that scientific observations are first understood in a logically coherent manner before they are modeled mathematically. However, because logic cannot always be implemented as systematically as mathematics, the Laws of Existence are introduced as formal rules to facilitate this process. Using these Laws of Existence, a universal structure, denoted as $U_{L,\beta}$, is formulated to provide a framework in which well-established scientific observations can be explained without paradoxes. This approach offers logically consistent interpretations of phenomena such as non-locality, superposition, and time dilation, and allows for efficient unification.

8 ACKNOWLEDGMENTS

I'd like to express my sincere gratitude to the physicists, mathematicians, experimentalists, and logicians that have provided the tools necessary to develop this work. I also acknowledge the profound philosophical insights found in the King James Version of the Bible, which have provided foundational inspiration for many of the ideas presented herein. Verses such as "things which are seen were not made of things which do appear," "for the things which are seen are temporal; but the things which are not seen are eternal," and "In the beginning, God created the heavens" have offered meaningful conceptual guidance. "God is not the author of confusion" further reinforces the premise that the universe is fundamentally coherent, a guiding assumption of this framework.

9 STATEMENTS AND DECLARATIONS

This manuscript was prepared without external funding. The author declares no competing interests relevant to this work. No new empirical data was generated or analyzed in this study; therefore, no data requires deposition. While AI tools (ChatGPT and Gemini) aided in formatting, this work is the result of the author's own intellectual effort, and as such the author takes full responsibility for it.

References

- [1] R. Smullyan, *Theory of Formal Systems*. Princeton University Press, 1961, pp. 4, 12–13.
- [2] J. S. Bell, “On the einstein podolsky rosen paradox,” *Physics Physique*, vol. 1, no. 3, pp. 195–200, 1964. [Online]. Available: <https://journals.aps.org/ppf/abstract/10.1103/PhysicsPhysiqueFizika.1.195>
- [3] E. Mendelson, *Introduction to Mathematical Logic*, 5th ed. CRC Press, 2009, pp. 149–308.
- [4] R. Descartes, *Principia Philosophiae*. Amstelodami: Apud Ludovicum Elzevirium, 1644, discusses plenum, subtle matter, and vortex theory in Parts II and III.
- [5] E. T. Whittaker, *A History of the Theories of Aether and Electricity: From the Age of Descartes to the Close of the Nineteenth Century*. London and New York: Longmans, Green and Co., 1910, see p. 301 for discussion of Maxwell’s aether and field equilibrium.
- [6] A. A. Michelson and E. W. Morley, “On the relative motion of the earth and the luminiferous ether,” *The American Journal of Science*, vol. 34, no. 203, pp. 333–345, November 1887.
- [7] A. Einstein, “Zur elektrodynamik bewegter körper,” *Annalen der Physik*, vol. 17, pp. 891–921, 1905, english translation available in *The Principle of Relativity*, Dover Publications, 1923/1952. [Online]. Available: <https://einsteinpapers.press.princeton.edu/vol2-trans/154>
- [8] ——, “Die feldgleichungen der gravitation,” *Sitzungsberichte der Königlich Preußischen Akademie der Wissenschaften (Berlin)*, pp. 844–847, 1915.
- [9] J. van Dongen, “On the role of the Michelson–Morley experiment: Einstein in Chicago,” *Archive for History of Exact Sciences*, vol. 63, no. 6, pp. 655–663, 2009.
- [10] LIGO Scientific Collaboration. (2016) Gravitational waves detected 100 years after Einstein’s prediction. Accessed: 2025-06-08. [Online]. Available: <https://www.ligo.caltech.edu/news/ligo20160211>
- [11] N. Landsman and L. Ruetsche. (2024) Quantum entanglement and information. Accessed: 2025-06-08. [Online]. Available: <https://plato.stanford.edu/archives/spr2024/entries/qt-entangle/>
- [12] J. S. Bell, “Bertlmann’s socks and the nature of reality,” in *Speakable and Unspeakable in Quantum Mechanics*. Cambridge University Press, 1987, pp. 139–158, originally published as an essay in 1980.
- [13] A. Einstein, B. Podolsky, and N. Rosen, “Can quantum-mechanical description of physical reality be considered complete?” *Physical Review*, vol. 47, no. 10, pp. 777–780, 1935. [Online]. Available: <https://journals.aps.org/pr/abstract/10.1103/PhysRev.47.777>
- [14] B. Hensen, H. Bernien, A. C. Dreau, A. Reiserer, N. Kalb, M. S. Blok *et al.*, “Loophole-free bell inequality violation using electron spins separated by 1.3 kilometres,” *Nature*, vol. 526, no. 7575, pp. 682–686, 2015. [Online]. Available: <https://www.nature.com/articles/nature15759>
- [15] T. Maudlin, “What bell did,” *Journal of Physics A: Mathematical and Theoretical*, vol. 47, no. 42, p. 424010, 2014. [Online]. Available: <https://doi.org/10.1088/1751-8113/47/42/424010>
- [16] S. M. Carroll, *Spacetime and Geometry: An Introduction to General Relativity*. San Francisco: Addison-Wesley, 2004, see especially pp. 3–5, 11–13 for discussion of light cones and the invariant speed of light in spacetime.
- [17] J. Maldacena and L. Susskind, “Cool horizons for entangled black holes,” *arXiv preprint arXiv:1306.0533*, 2013. [Online]. Available: <https://arxiv.org/abs/1306.0533>
- [18] D. W. Thomson III and J. D. Bourassa, “The aether physics model: A novel framework for unifying quantum mechanics and general relativity,” *Journal of Physics: Applications and Mechanics*, vol. 1, no. 1, 2024. [Online]. Available: <https://www.jscimedcentral.com/journal-article-info/Journal-of-Physics-Applications-and-Mechanics/The-Aether-Physics-Model-A-Novel-Framework-for-Unifying-Quantum-Mechanics-and-General-Relativity-11961>

- [19] L. S. Brown, *Quantum Field Theory*. Cambridge University Press, 1992, pp. 186–188.
- [20] R. M. Wald, *General Relativity*. University of Chicago Press, 1984, p. 23.

A MATHEMATICAL PROOFS

These mathematical proofs are used above to derive Laws of Existence. They are based on mathematical theorems that are fundamental to physics to ensure that they can't reasonably be argued against.

Zero To Infinity Theorem (ZTIT)

Purpose: In mathematics, variables can grow without bound, tending towards infinity, but in physics, it is often necessary to assume that infinity has already been reached. For instance, if an entity Z has always existed, its past is infinite, not approaching infinite. This theorem asserts that infinities cannot be used to generate non-zero values from zero, similar to the impossibility of creating something from nothing.

Claim: $0 \cdot g(x) = 0$ or it is undefined, $\forall g(x) \in \mathbb{C} \cup \{\infty\}$.

Proof: Modern physics can be developed without the Riemann Sphere, but can't be developed without the real and complex planes. Consequently, it is essential to provide proofs that align with the established assumptions on which physics depends. Let \mathbb{C}_∞ denote the set $\mathbb{C} \cup \{\infty\}$, where ∞ represents points formally adjoined to the complex plane, distinct from its interpretation in the Riemann Sphere. If $0 \cdot g(x)$ is defined, then there exists some $z \in \mathbb{C}_\infty$ such that:

$$0 \cdot g(x) = z$$

We now proceed under this assumption and examine the consequences. First, consider:

$$(2 \cdot 0) \cdot g(x) = 2z$$

Since $2 \cdot 0 = 0$, it follows that:

$$0 \cdot g(x) = 2z$$

By the original assumption $0 \cdot g(x) = z$, we substitute:

$$z = 2z$$

Rearranging:

$$2z - z = 0$$

$$z = 0$$

Thus, we conclude that $0 \cdot g(x) = 0, \forall g(x) \in \mathbb{C}_\infty$ or the expression is undefined.

Perhaps the most intuitive way to establish this is to map 0 to the thickness of a line-segment, and $g(x)$ to its length, to conclude that the area is always 0.

QED

Non-Zero Limit Theorem (NZLT)

Purpose: Since $f(x)$, as defined below, can't be made point-like, this establishes that limits can't be applied to point particles (to yield a non-zero value).

Claim: Given $f(x)$ and $g(x) | \lim_{x \rightarrow a} g(x) \neq 0$, if $\lim_{x \rightarrow a} f(x)g(x) \neq 0$, then $\lim_{x \rightarrow a} f(x) \neq 0$.

Proof:

$$\begin{aligned} \lim_{x \rightarrow a} f(x)g(x) &\not\equiv 0 \\ \lim_{x \rightarrow a} f(x)g(x) &\not\equiv \lim_{x \rightarrow a} 0 \cdot g(x) \quad (\text{by the ZTIT}) \\ \therefore \lim_{x \rightarrow a} f(x) &\not\equiv 0 \quad (\text{since } \lim_{x \rightarrow a} g(x) \neq 0) \end{aligned}$$

For example: $\lim_{x \rightarrow \infty} 1/x = 0$, but $\nexists x \in \mathbb{C}_\infty | 1 = 0 \cdot x$ (by the ZTIT), and thus $\lim_{x \rightarrow \infty} 1/x \not\equiv 0$.

QED

Dirac Delta Function Theorem (DDFT)

Claim: The Dirac delta function $\delta(x - \alpha)$ can't be applied to a point-particle.

Proof: The Dirac Delta Function is a distribution that picks out values of a function $f(x)$ such that $\int_{-\infty}^{\infty} f(x)\delta(x - \alpha)dx = f(\alpha)$. However, if we assume that $\delta(x - q_i) = 0 \forall x \notin \{q_1, q_2, q_3, \dots\}$, then:

$$\begin{aligned} \left| \int_{-\infty}^{\infty} f(x)\delta(x - \alpha) dx \right| &= \left(\left| \int_{-\infty}^{\infty} f(x)\delta(x - q_1) dx \right| \leq 0 \cdot \infty \right) + \dots \\ &= 0 + \dots \quad (\text{by the ZTIT}) \\ &= 0 \end{aligned}$$

Thus, the Dirac Delta function is not applicable when its nonzero interval is restricted to discrete points, as is the case for a point-particle. The Dirac Delta Function is primarily motivated by the limiting process in which the Bell Curve of the Gaussian distribution narrows to identically zero width. However, according to the NZLT, this limit is not achievable.

QED